

Global Water Cycle

Characterize, Understand and Predict



Global Water Cycle

The ***Global Water Cycle*** is the core of the climate system, physical, chemical, and ecological component and their interactions.

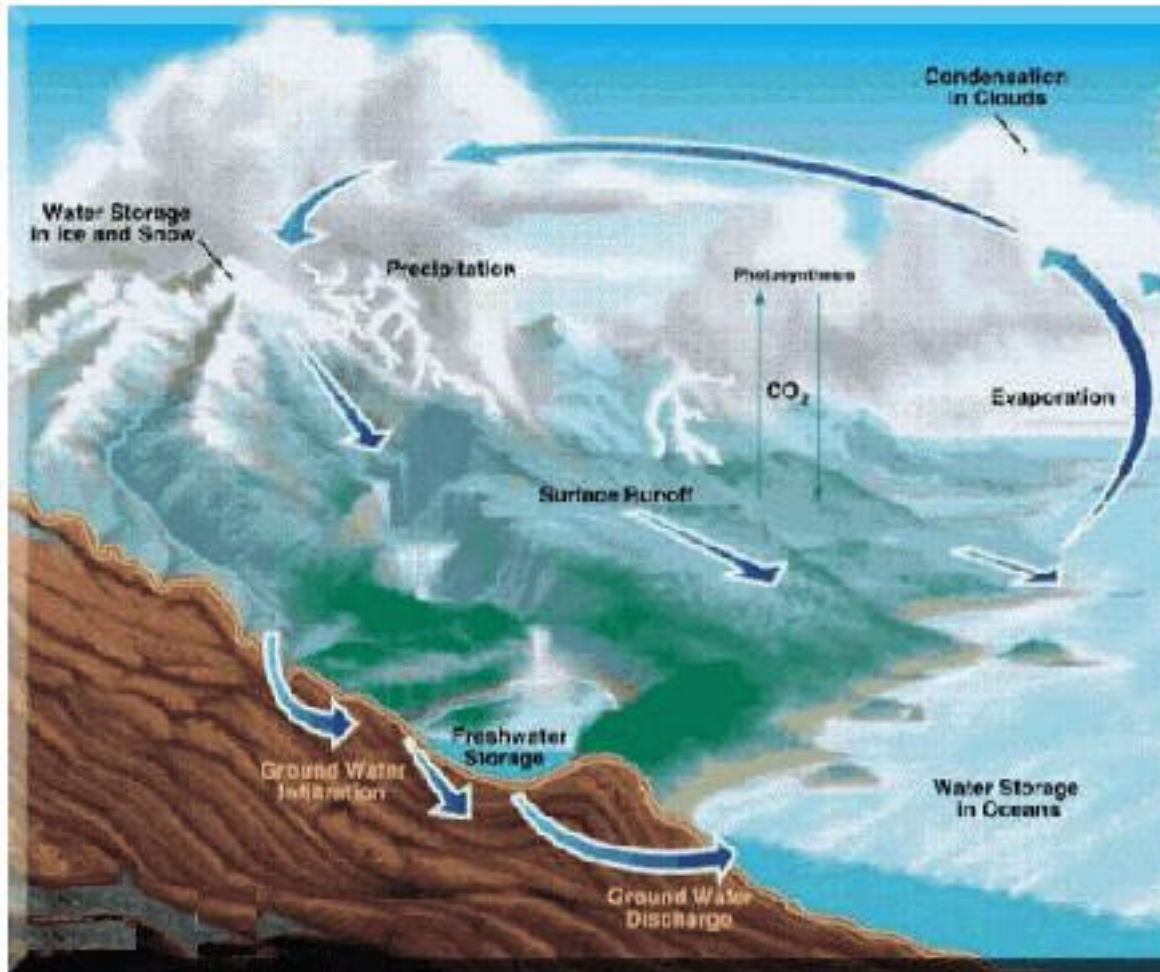
The Earth is unique; it functions at the “***triple point of water***” and coexists in all 3 phases – **ice**, **liquid** and **gas** in a variety of forms.

- **Ocean** – liquid water and sea ice
- **Atmosphere** – clouds, water vapor, liquid and frozen precipitation
- **Land** – lakes, reservoirs, streams, snow cover, soil moisture

Goal of the NASA water cycle research is to **characterize and predict the global partitioning of water** in its 3 phases and exchanges between the atmosphere, land and ocean.

Global Water Cycle

Reservoir and Flux Components



Top-level Questions

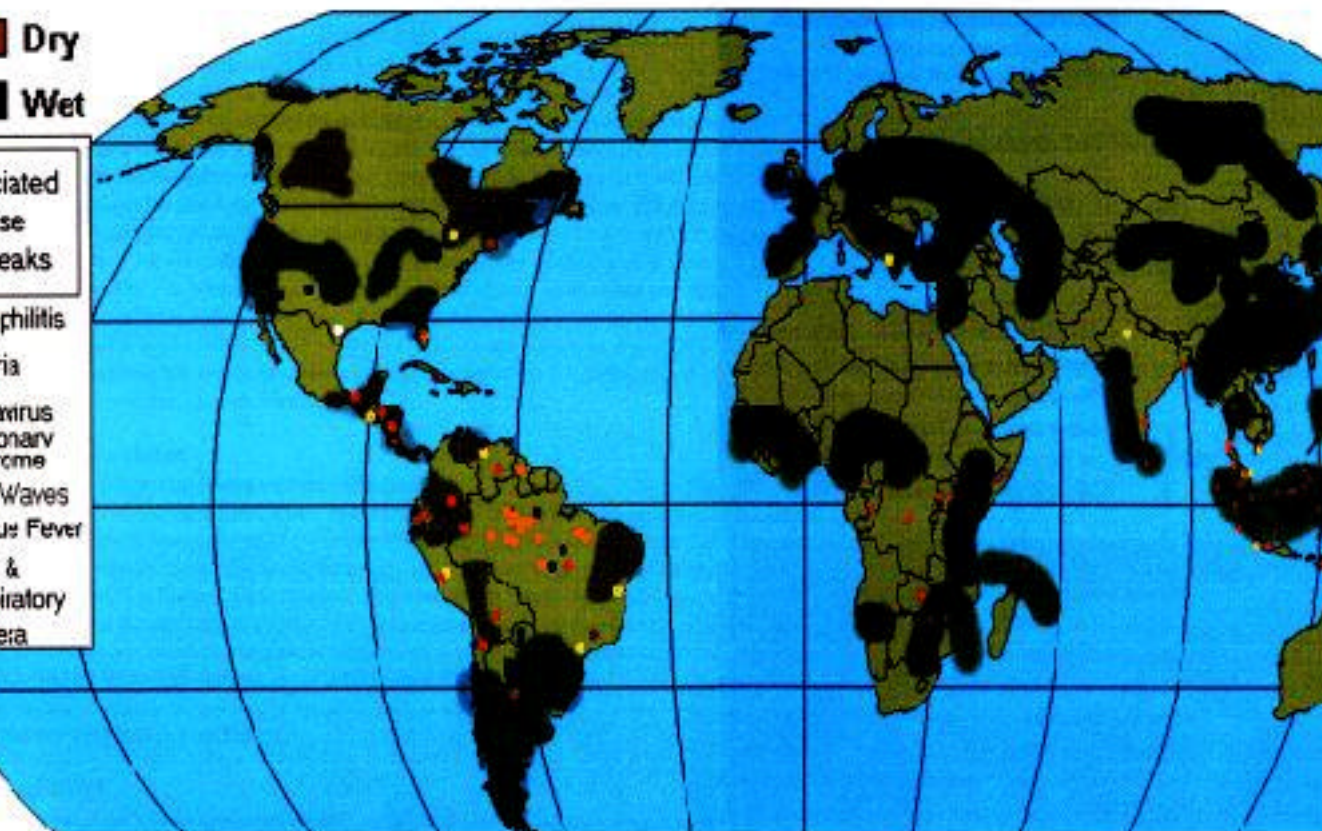
Are natural forcings and human influences causing the climate cycle and partitioning among its components to accelerate?

Do we have evidence of the intensification and/or reorganization of rainfall patterns, severe storm frequencies, drought frequencies, glacial melting etc.?

What are the potential consequences to agriculture, water resources, energy utilization and human health?

Global Precipitation Anomalies and Associated Diseases

June 1997-May 1998



Global Water Cycle Science Strategy Questions

Is the global water cycle ***accelerating***?

What are the effects of ***cloud*** and ***land surface hydrology*** on climate change?

How are ***variations in weather, precipitation, and water*** related to global climate change?

To what extent can ***weather forecasting*** be improved by ***observations*** and advances in satellite data assimilation?

Will climate variations induce major ***change in the deep*** ocean?

Can climate variations be ***understood*** and ***predicted***?

What we know.

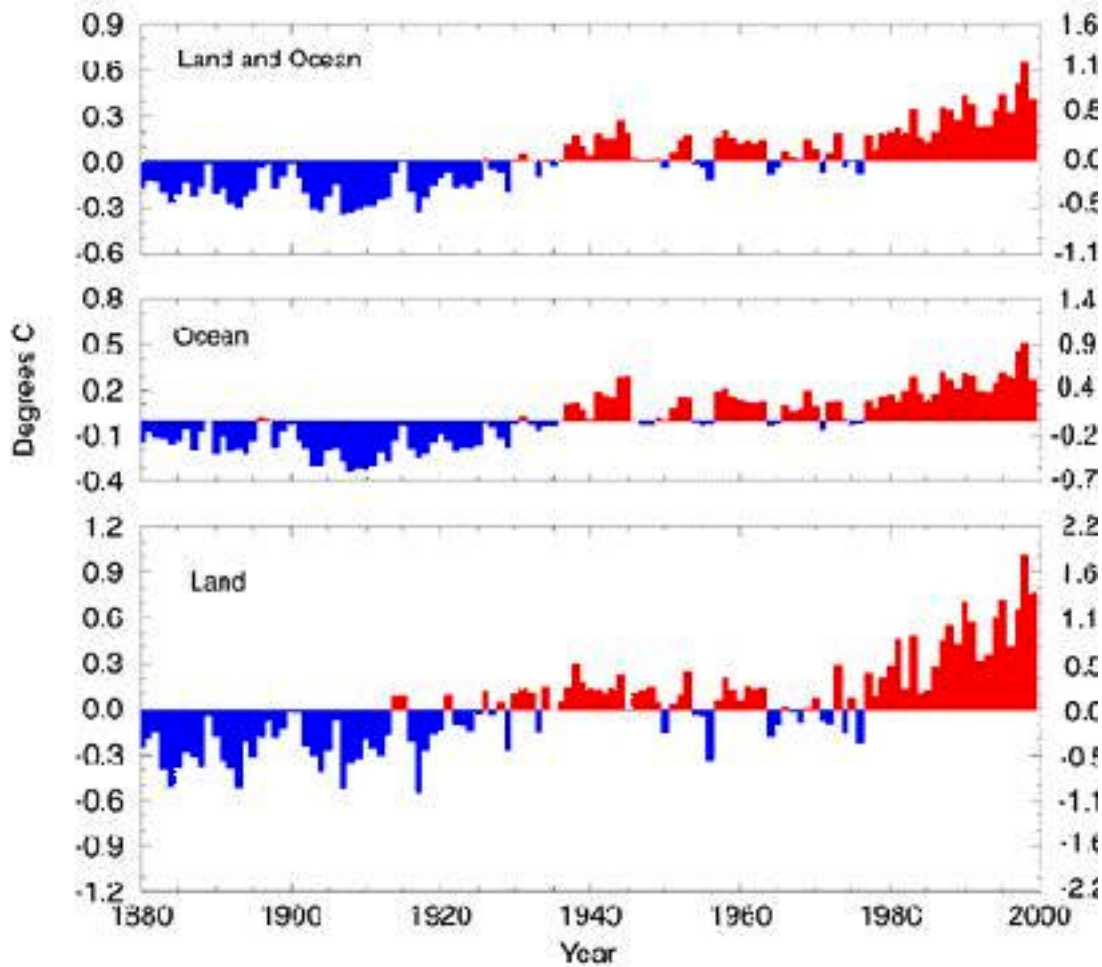
Definite ***20-year upward trends in global mean surface***
and regional temperatures over most parts of the globe (N

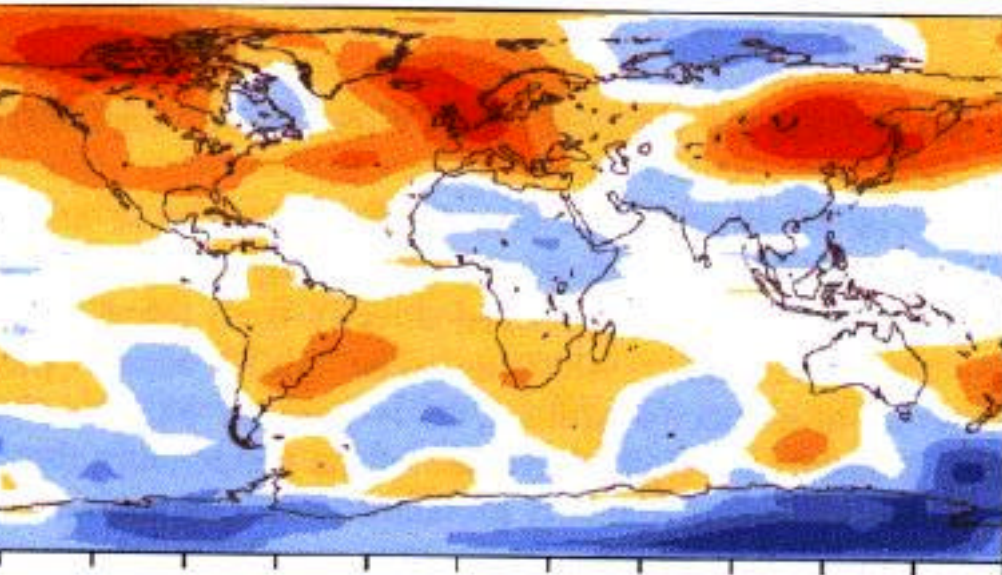
Regional trends in tropospheric temperature; ***no clear gl***

Existing global measurements/remote sensing of cloud
precipitation, water vapor are either ***not accurate*** enough
enough ***to identify definite trends***.

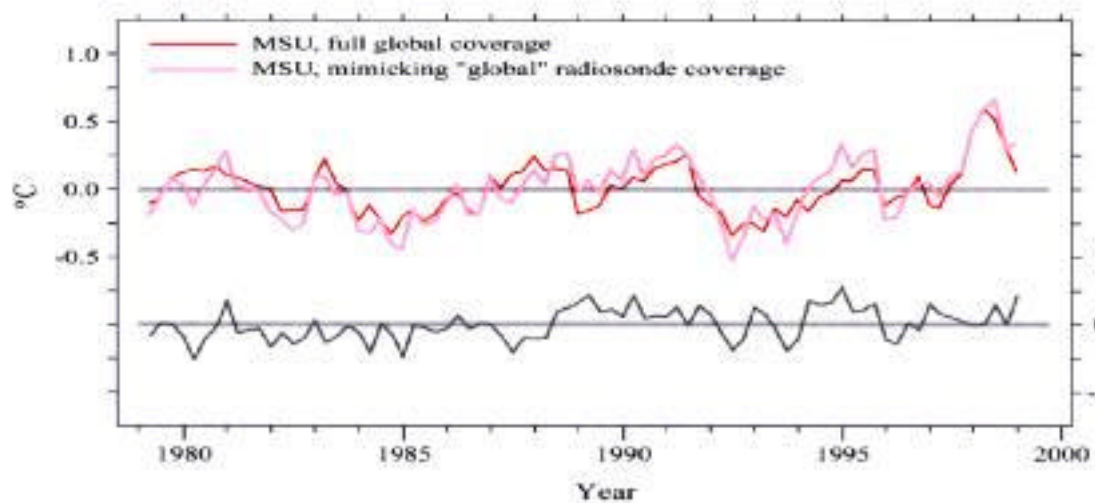
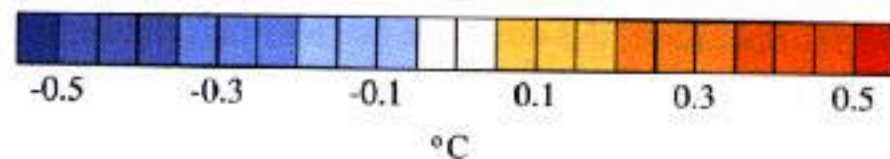
Annual Global Surface Mean Temperature Anomalies

National Climatic Data Center/NESDIS/NOAA





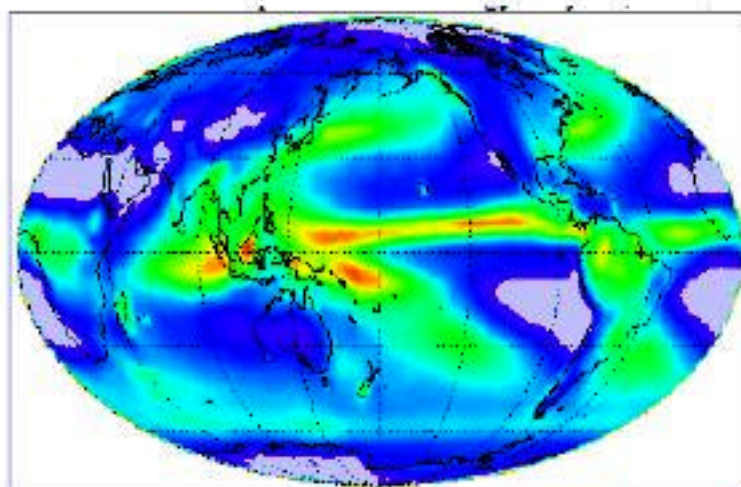
**Mid-Tr
Ten**



Key Global Measurements

Not Capable of Identifying Trends

Precipitation



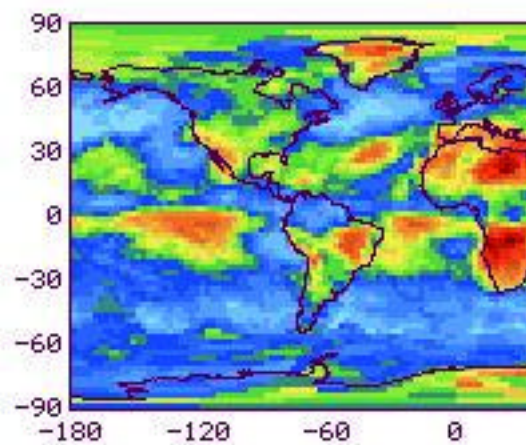
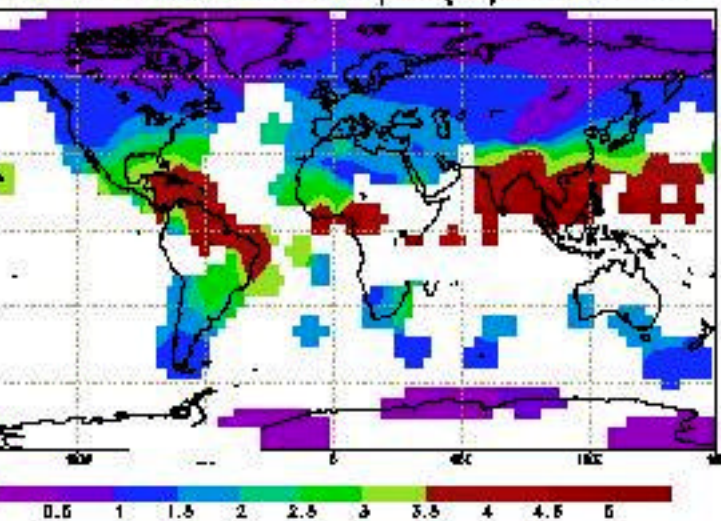
5 (mm day⁻¹)

10

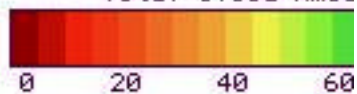
Cloud

Water Vapor

2UTC Annual Mean Water Vapor (cm) Below 500mb



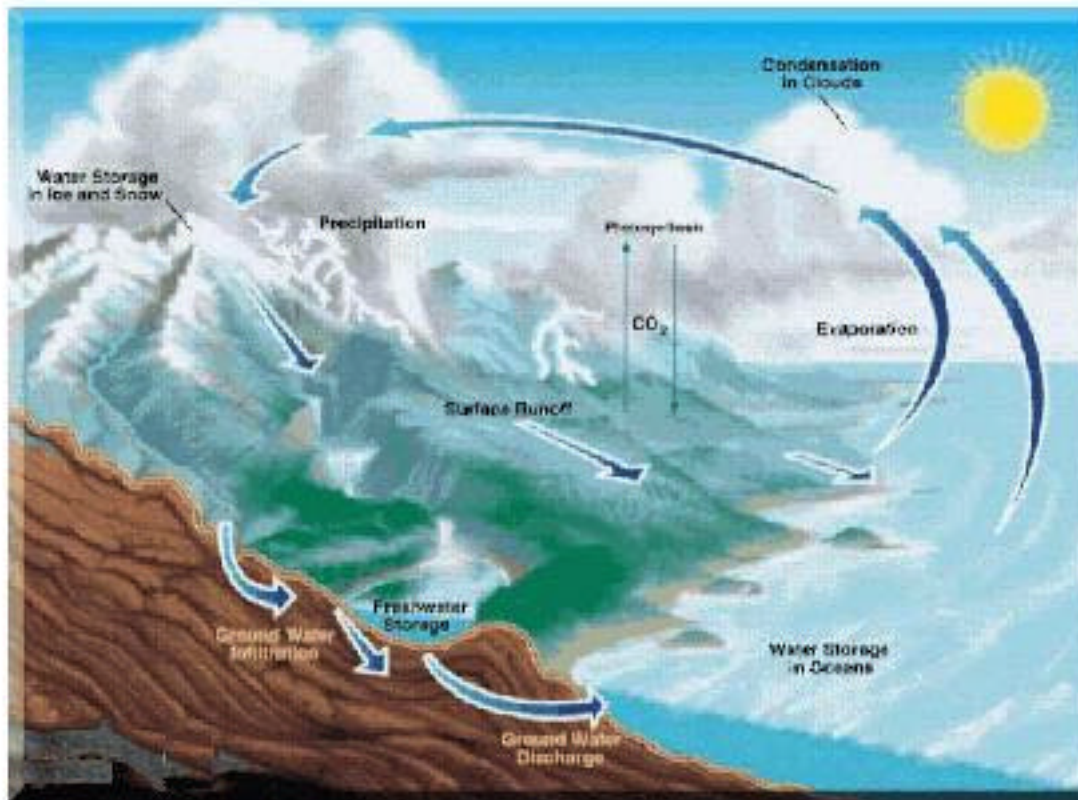
Total Cloud Amount



What do we need to know?

- **Identify significant trends in the global water cycle** and the extent to which observed changes match model predictions.
- The extent to which changes in the frequency, intensity, and path of weather systems, which produce drought and replenish fresh water resources, can be related to such climate trends.
- What **climate surprises** may be in store for the future (rapid melting of Arctic sea-ice, or loss of the ocean circulation of the Atlantic ocean).

What do we need to know



- Evidence of significant trends
- Impacts of increased variability
- Early warning of climate surprises

What will EOS and other missions tell us about Earth's climate system?

Baseline **atmospheric temperature record** enabling determination of decadal trend in the course of the next 10-15 years. [AIRS]

Baseline **atmospheric humidity record** enabling the identification of global/regional trends differentiated by altitude layer. [AIRS]

Structure of selected weather systems and quantitative relationships between **precipitation rate** [Seawinds, TRMM, and Aqua/AMSR]

Baseline determination of **net radiation budgets** by regions and total equator-to-pole energy transport. [CERES]

3-dimensional distribution of **atmospheric radiative heating** at surface, in relationship with organized weather systems and [Aqua/MODIS, CERES, AIRS, AMSR, Cloudsat, PICASSO]

Variability in **snow accumulation** over polar ice caps. [ICESat]

What is required?

Characterizing long-term changes in:

Sea surface temperature: most reliable indicator of historical climate variability; significant controlling parameter for air-sea fluxes.

Atmospheric temperature and humidity: state of atmospheric climate, and weather disturbances.

Global precipitation: precipitation is the most significant aspect of climate change from perspective of human interests and the health of ecosystems.

Soil moisture, snow accumulation, and ocean surface salinity: cumulative climate change on the fresh water budget of land and ocean.

Ocean surface winds: controlling parameter for air-sea fluxes, and most informative indicator of the strength of weather systems over the oceans (where weather systems are most clearly defined and understood).

What is required?

Improved understanding:

- **Evaporation** from the global ocean [80% of water present in the atmosphere comes from the ocean].
- **Land surface hydrologic processes** which govern **evapotranspiration** partitioning of rainfall between re-evaporation, storage in the soil, and runoff in rivers.
- Relationships across spatial and temporal scales between global atmospheric climate and **regional weather systems** which:
 - Are the principal manifestation of climate change on society
 - Govern clouds & rainfall, and control variable water and energy fluxes.
- Role of **microphysical processes** (notably aerosol cloud condensation nuclei, cloud formation and the Earth radiation budget).

What is required?

Improved Prediction:

- **Short-term weather** in order to:
 - Contribute to the science of weather forecasting and support of operational prediction centers, and
 - Enable scientific investigations of weather-related processes (e. g. clouds etc.)
- **Transient climate variations** (e. g. ENSO) in order to:
 - Contribute to the science of short-range climate forecasting in support of environmental prediction centers, and
 - Enable identifying long-term climate trends among random natural climate variability
- **Long-term climate trends** in order to:
 - Predict the range of potential future climate change as required for policy
 - Assess potential risk for rapid climatic transitions or surprises

What we propose to do

Systematic Observations

Atmospheric temperature and water vapor

Plan \Rightarrow Transition to NPP and operational NPOESS.

Global precipitation

Plan \Rightarrow Full-scale demonstration (Global Precipitation Mission)

Soil moisture and snow

Plan \Rightarrow Exploratory missions and technology development enable new mea

Ocean winds

Plan \Rightarrow Implement Seawinds on Japan's ADEOS-2 mission and preserve similar sensors on Japan's GCOM satellite series [decision in 2002, based on Coriolis in-space test of the experimental passive measurement techniques NPOESS].

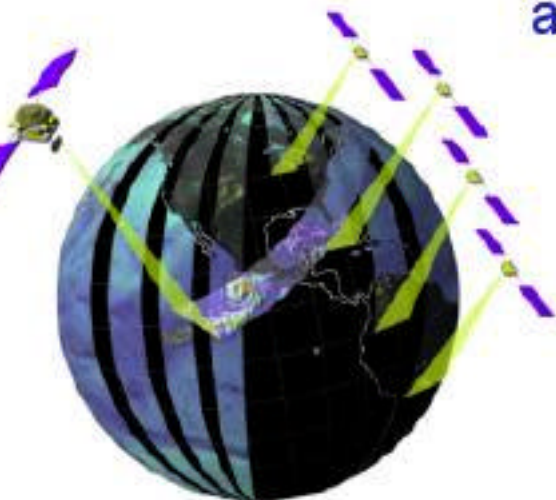
Sea-Surface Temperature: Operational

What we propose to do

Systematic Observations

Global Precipitation Mission

Understand the global structure of rainfall and its impact on Earth's habitability.



3hr Global
observation using a
constellation of
satellites



What we propose to do

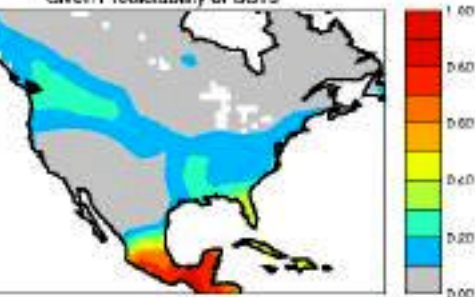
Exploratory Observations

Soil Moisture Mission

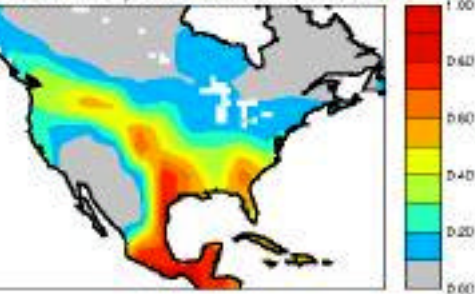
Understand the impact of soil moisture and on flood/drought prediction, weather forecasting, and agriculture.

Index of Precipitation Predictability (JJA):

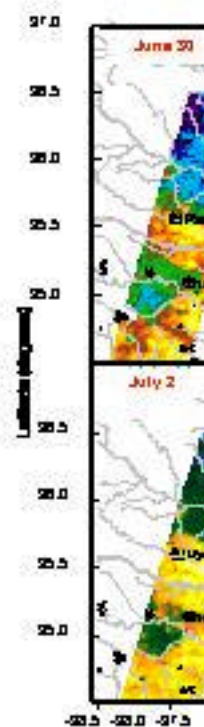
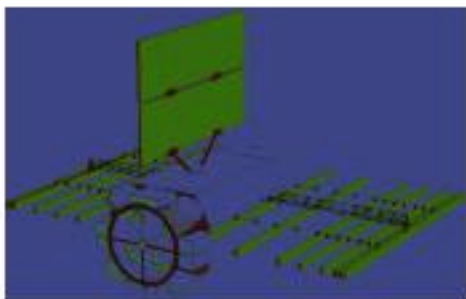
Given Predictability of SSTs



Index of Precipitation Predictability (JJA):



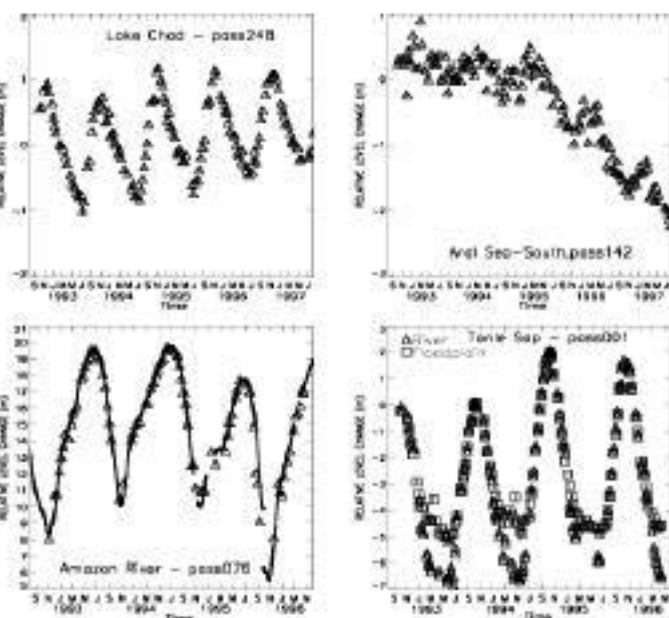
Global soil moisture
observation using a
microwave
radiometer



What we propose to do Future Exploratory Observations

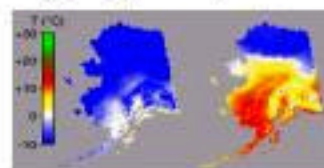
New observations are critical in understanding and
the global water cycle

Hydrologic Altimetry Mission:

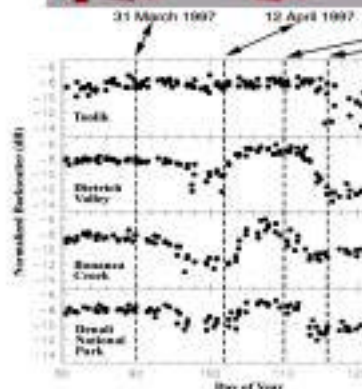


Cold-Seasons Hydrology

Daily average air temperature



NSCAT freeze-thaw state



What we propose to do:

Exploratory/Process-research Missions

Cold climate hydrology processes measurement of :
accumulation; freeze/thaw transitions.

Quantification of low-level atmospheric water vapour
microwave (GPS) occultation.

Gravimetric determination of changes in snow, soil moisture, and ground water storage through mapping of the time-dependent component of the Earth's gravity field.

Ocean Surface Salinity.

Structure of organized weather systems based on observations of tropospheric winds.

Altimetric measurement of the stage height of inland water bodies.

What we propose to do

Technology Investments

Moderate resolution (1-10km) **radar or scatterometer** systems for measurement of microwave backscatter at low microwave frequencies for measurement of **soil moisture**, **snow** water equivalent, soil **free**

Large-size real or synthetic **antenna systems** for radiometric imaging properties at low microwave frequencies.

Ultra-sensitive **gravity field** measurements. Application to "photon-lensing" of changes in mass distribution on Earth.

High pulse-repetition rate **lidar** systems. Application: lidar mapping rivers, inland water bodies, etc.

High-power **lidar** systems for wind observation.

What we propose to do

Research and Modeling

Global Planetary Boundary Layer (PBL) research

PBL processes are key to the estimation of air-sea fluxes over the oceans, and to fluxes over land. [e. g. Quikscat science team]

Surface Hydrologic Processes

Land surface processes, vegetation, and turbulent fluxes govern water and energy budget and partitioning of rain among evaporation, storage and runoff. [e. g. Land Surface Hydrology]

Water vapor research

Role of weather systems and convective clouds as sources or sinks of water vapor in the troposphere. [e. g. Atmospheric Dynamics and Physics Program]

Clouds and Radiation research

Role of water in its three physical states in radiation transfer. [e. g. PICASSO & Earth Radiation Budget Experiment; sensing of cloud and aerosol properties; CRYSTAL and CAMEX field campaigns]

Climate modeling

Simulation of natural (unforced) climate variability. [e. g. GISS]

Is the Global Water Cycle **accelerating**
and what will **consequences** be for weather
and water resources?

Forcing:

Extended-range Weather Forecast

Prediction of seasonal climate
anomalies

Assessment of long-term climate
sensitivity & trends

Water resource and river basin
management

Sustainability of water uses

← Greenhouse effect

← Ocean circulation

← Land cover modification

← Growing human population
water consumption

← Growing industrial
agricultural consumption

Expected Scientific Achievements by :

Characterization:

Decadal trend in global rainfall rate and water content of the atmosphere
Time-dependent distribution of soil moisture over continents

Understanding:

3-D structure of clouds and their relationship to weather systems
Indirect radiative forcing by aerosols through modification of cloud properties
Effect of soil moisture and snow on land-atmosphere water fluxes

Prediction:

Impact of global precipitation observations on predicting river flow and
Impact of new observations, advanced general circulation models, and
New methods on the skill of weather prediction beyond 5 days

Back-up Slides

Science Strategy Questions Not Being Addressed Under Global Water Cycle Research

How is the ocean circulation varying on climatic time scales?

Are polar ice sheets losing mass as a result of climate change?

Will changes in polar ice sheets cause a major change in global climate?

To what extent can long-term climate trends be assessed and predicted?